CLAIMS

What is claimed is:

1. An electron source comprising:

a substrate;

a cathode disposed over the substrate, the cathode for providing a source of electrons;

an emitter layer disposed over the cathode and formed from a composition of an embedding material and a plurality of nano-structures embedded therein, the emitter layer having a surface at which ends of the nano-structures are truncated and exposed for emitting electrons;

an insulator disposed over the emitter layer, the insulator having one or a plurality of apertures for exposing the ends of the nano-structures; and

a gate electrode disposed over the insulator and having one or a plurality of apertures that are aligned with the apertures in the insulator, the gate electrode for controlling the emission of electrons through the apertures from the exposed nano-structures.

2. An electron source as recited in claim 1,

wherein a vacuum is present in the apertures of the gate electrode and the insulator; and

wherein an electric field is present in the vacuum between the exposed ends of the nano-structures in the surface of the emitter layer and the gate electrode, the electric field having an intensity that is increased over its vacuum intensity by the presence of the embedding material in the emitter layer.

3. An electron source as recited in claim 1, wherein the exposed ends of the nano-structures are at substantially the same distance from the gate electrode.

4. An electron source as recited in claim 1, wherein the embedding material is composed of a single material.

5. An electron source as recited in claim 1, wherein the embedding material is composed of

multiple different materials.

6. An electron source as recited in claim 1, wherein the nano-structure has at least one of its three dimensions in the nanometer range.

7. An electron field emission composite as recited in claim 6, wherein the nano-structure includes nano-tube, nanowires, nano-cone, nano-fiber, nano-particle, and nano-plane.

8. An electron source as recited in claim 1, wherein the nano-structure is grown in alignment and with controlled spacing between nano-structures.

9. An electron source as recited in claim 1, wherein the nano-structures are grown randomly.

10. An electron source as recited in claim 1, wherein the nano-structures are prefabricated.

11. An electron source as recited in claim 1, wherein the exposed end of the nano-structure is slightly recessed from the surface of the emitter layer.

12. An electron source as recited in claim 1, wherein the exposed end of the nano-structure protrudes slightly from the surface of the emitter layer.

13. An electron source as recited in claim 1, wherein the nano-structures are exposed by a chemical mechanical planarization process.

14. An electron source as recited in claim 1, wherein the nano-structures are exposed by a combination of lithography and chemical etch.

15. An electron source as recited in claim 1, wherein the surface of the emitter layer is treated to induce atomic bonding to the ends of the truncated nano-structures.

16. An electron source as recited in claim 1, wherein the nano-structures are conductive and

the embedding material is an insulating material.

17. An electron source as recited in claim 16, wherein the insulating material that is selected from a group of materials consisting of: ferroelectric materials, oxides, nitrides, carbides, diamond-like carbon, un-doped semiconductors, glasses, organically modified glasses, insulating ceramics and composites, and cured organic resins.

18. An electron source as recited in claim 16, wherein the conductive nano-structures are selected from a group of materials consisting of: carbon, doped-semiconductor, refractory metals and alloys, and conductive ceramics.

19. An electron source as recited in claim 18, wherein the carbon includes carbon nano-tube, carbon nano-fiber, carbon nano-cone, carbon nano-particle and carbon nano-plane.

20. An electron source as recited in claim 16, wherein the conductive nano-structures are formed from an insulating core and a conductive shell.

21. An electron source as recited in claim 20, wherein the insulating core is a wide band gap semiconductor that includes AlN, AlGaN, BN, SiC, diamond, GaN.

22. An electron source as recited in claim 16, wherein the conductive nano-structures are grown directly on the substrate.

23. An electron source as recited in claim 22, wherein the conductive nano-structures are grown randomly.

24. An electron source as recited in claim 22, wherein the conductive nano-structures are grown with alignment and controlled spacing.

25. An electron source as recited in claim 20, wherein the conductive nano-structures are a composite structure having alternating insulating and conductive layers.

26. An electron source as recited in claim 1, wherein the embedding material is conductive and nano-structures are insulators.

27. An electron source as recited in claim 26, wherein the insulator nano-structures are grown on the substrate with alignment and controlled spacing between nano-structures.

28. An electron source as recited in claim 26, wherein the insulator nano-structures are grown randomly on the substrate.

29. An electron source as recited in claim 26, wherein the insulator nano-structures are pre-fabricated and deposited on the substrate by printing, spin coating, extrusion coating, dipping, and doctor blade.

30. An electron source as recited in claim 26, wherein the insulator nano-structures are selected from a group consisting of: wide band gap semiconductors, oxides, carbides, nitrides and semiconductors.

31. An electron source as recited in claim 30, wherein the wide-band semiconductors include diamond, BN, GaN, AIN, AIGaN, GaAs, SiC, ZnO.

32. An electron source as recited in claim 26, wherein the conductive embedding material is selected from the group consisting of: conductive ceramics, conductive composites, metals, metal alloys, doped semiconductors, and conductive polymers.

33. An electron source as recited in claim 32, wherein the conductive composites include carbon dispersed in glasses.

34. An electron source as recited in claim 1, wherein the nano-structures are conductive and the embedding material is conductive.

35. An electron source as recited in claim 34, wherein the conductive nano-structures are selected from a group of materials consisting of: carbon, refractory metals, refractory alloys, conductive ceramics, and doped semiconductors.

36. An electron source as recited in claim 35, wherein carbon includes carbon nano-tube, carbon nano-fiber, carbon nano-cone, carbon nano-particles, and carbon nano-planes.

37. An electron source as recited in claim 34, wherein the conductive nano-structures are grown directly on the substrate.

38. An electron source as recited in claim 34, wherein the conductive nano-structures are pre-fabricated.

39. An electron source as recited in claim 34, wherein the conductive nano-structures are pre-fabricated and deposited on the substrate by printing, spin coating, extrusion coating, dipping, and doctor blade.

40. An electron source as recited in claim 34, wherein the conductive embedding material is selected from the group consisting of: refractory metals, refractory alloys, conductive ceramics, conductive composites, doped semiconductor thin films, and conductive polymers.

41. An electron source as recited in claim 40, wherein the conductive composites include carbon dispersed in glasses.

42. An electron source as is recited is claim 1,

wherein the cathode electron is configured as rows of substantially parallel strips, each cathode strip for providing an independent source of electrons;

wherein the gate electrode is configured as columns of substantially parallel strips, each column strip intersecting with the rows of cathode strips at intersection patches and having one or a plurality of apertures at each intersection patch, wherein each gate electrode is configured to control the emission of electrons through the apertures along the gate

electrode; and

wherein activation of a selected cathode strip and a selected gate electrode strip determine the intersection patches that emit electrons.

43. An electron source comprising:

a substrate;

a cathode disposed over the substrate and having side walls, the cathode for providing a source of electrons;

an emitter layer disposed over a side wall of the cathode and formed from a composition of an embedding material and one or a plurality of nano-structures embedded therein, the emitter layer having a surface at which ends of the nanostructures are truncated and exposed for emitting electrons; and

a gate electrode disposed over the substrate and having a side wall spaced apart from and facing the emitter layer, the gate electrode for controlling the emission of electrons from the exposed nano-structures of the facing emitter layer.

44. An electron source as recited in claim 43, wherein the nano-structures have ends that are slightly recessed from the surface of the emitter layer.

45. A method of fabricating an electron source, the method comprising:

providing a substrate;

depositing on the substrate a first conductive layer;

depositing on the first conductive layer an emitter layer composed of an embedding material and one or plurality of nano-structures embedded therein;

truncating and exposing the ends of the nano-structures by polishing the surface of the emitter layer;

depositing an insulator over the polished surface of the emitter layer;

depositing second conductive layer over the insulator; and

removing portions of second conductive layer and insulator to form apertures therein and expose the ends of the nano-structures for emission.

46. A method as recited in claim 45, wherein depositing an emitter layer includes:

depositing on the first conductive layer a thin catalyst layer of nano-sized dots;

growing an array of vertically-aligned nano-structures from the catalyst dots; and

depositing a material to embed the nano-structures, the embedding material and nano-structures forming the emitter layer with a surface at which ends of the nano-structures are to be exposed.

47. A method as recited in claim 46, wherein the nano-structures include carbon nanotubes, carbon nanofibers and carbon nanocones.

48. A method as recited in claim 47, wherein the embedding material is an insulator.

49. A method as recited in claim 48, wherein the insulator is SiO_2.

50. A method as recited in claim 45, wherein depositing the emitter layer includes:

dispersing pre-fabricated nano-structures in a slurry to form an uniform mixture;

depositing the uniform mixture on the first conductive layer;

drying the uniform mixture; and

heating at a high temperature to form the emitter layer with a surface at which ends of the nano-structures are to be exposed.

51. A method as recited in claim 45, wherein depositing the emitter layer includes:

dispersing pre-fabricated nano-structures in a precursor solution;

coating the first conductive layer with the solution; and

condensing the precursor solution to form the emitter layer with a surface at which ends of the nano-structures are to be exposed.

52. A method as recited in claim 45, wherein the polishing is performed by chemical-mechanical planarization.

53. A method as recited in claim 45,

wherein the embedding material is comprised of at least two layers; and

further comprising:

depositing the first layer by vapor deposition; and

depositing the second layer by disposing a fluidic precursor onto the substrate and curing or condensing the precursor by heating or illumination.

54. A method as recited in claim 45, further comprising the step of depositing and patterning an etch-stopper prior to truncating and exposing the ends of the nano-structures by polishing the surface of the emitter layer.

55. An electron source comprising:

a substrate;

electrode means, disposed over the substrate, for providing a source of electrons;

means, disposed over the source means, for emitting electrons provided by the source means into a vacuum, the emitting means including nano-structure emitting means for providing a flow of electrons and field-enhancement means for lowering a threshold field at which the emitting means emits electrons;

an insulator disposed over the emitting means; and

gating means, disposed over the insulator, for controlling the flow electrons emitted by the emitting means.

56. An electron source as recited in claim 55, wherein the gating means and the insulator each include one or more apertures that expose the nano-structure emitting means to the vacuum.

57. An electron source as recited in claim 55, wherein the nano-structure emitting means is a conductive material and the field-enhancement means is an insulating material.

58. An electron source as recited in claim 55, wherein the nano-structure emitting means is an insulating material and the field-enhancement means is a conductive material.

59. An electron field emission composite comprising:

one or more nano-structures;

an embedding material in which the nano-structures are embedded, the embedding material having a surface at which ends of the embedded nano-structures are truncated and exposed, the exposed ends of the nano-structures configured to emit electrons when under the influence of an electric field applied in a vacuum proximate to the exposed ends.

60. An electron field emission composite as recited in claim 59, wherein the intensity of the applied electric field in vacuum is increased at the exposed tip of nano-structures by the presence of the embedding material.

61. An electron field emission composite as recited in claim 59, wherein the nano-structures are grown on a substrate.

62. An electron field emission composite as recited in claim 59,

wherein the nano-structures are pre-fabricated; and

wherein the embedding material is formed from a slurry.

63. An electron field emission composite as recited in claim 62,

wherein the nano-structures are insulators; and

wherein the embedding material is a conducting material.

64. An electron field emission composite as recited in claim 63, wherein the insulators are wide band gap semiconductors.

65. An electron field emission composite as recited in claim 64, wherein the wide band gap semiconductors include diamond, AlN, AlGaN, BN, SiC, GaN.

66. An electron field emission composite as recited in claim 62, wherein the slurry forms a conducting composite with carbon dispersed in glasses.

67. An electron field emission composite as recited in claim 62, wherein the pre-fabricated nano-structure is formed from carbon.

68. An electron field emission composite as recited in claim 67, wherein the carbon includes carbon nanotube, carbon nanofiber, carbon nanocone, carbon nanoplane and carbon nanoparticle.